Westinghouse

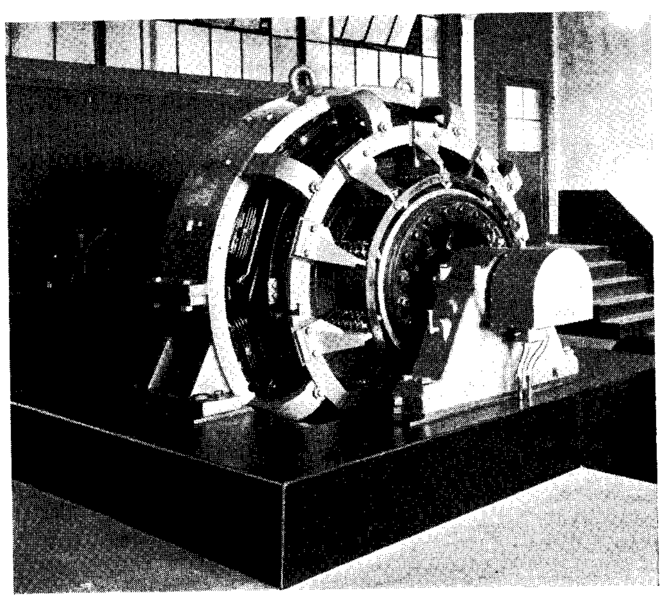
Direct-Current Generators and Motors

Installation

Operation

Maintenance

INSTRUCTION BOOK

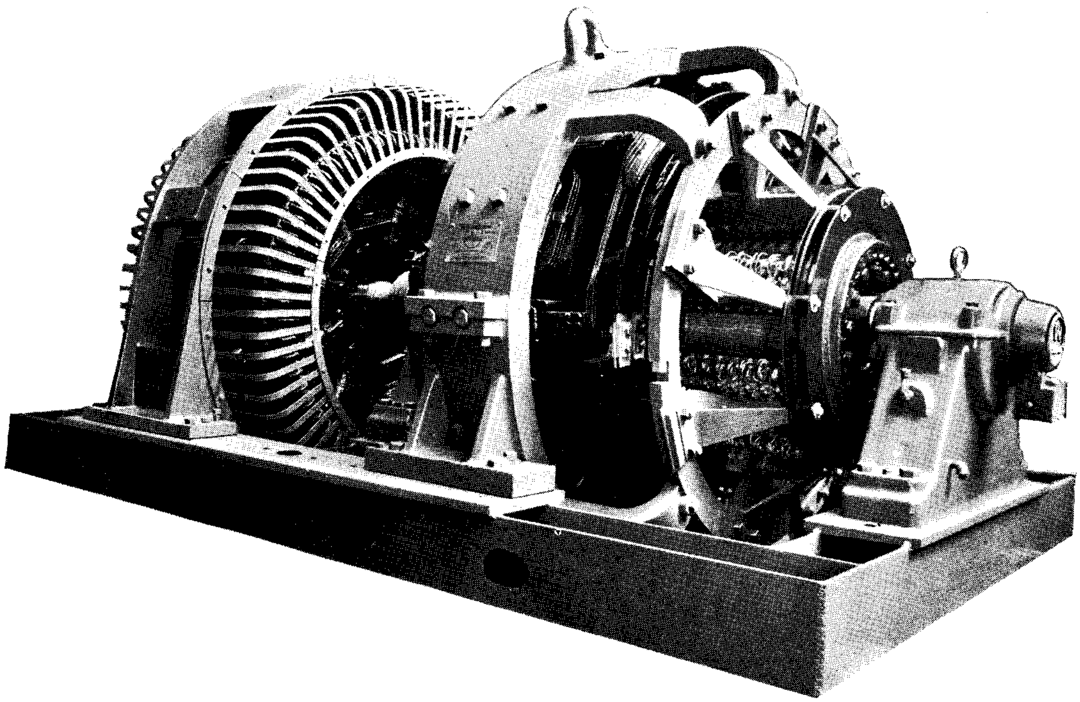


Installation of Westinghouse Type QS Motor

Westinghouse Electric & Manufacturing Company

East Pittsburgh Works, East Pittsburgh, Pa.

I. B. 5107-E



1000 Kw.—250 Volt—720 RPM 60 Cycle Motor-Generator

IMPORTANT

Keep the generator or motor clean. The finest machines and the most expensive plant may be shut down by accident if they do not have protection and care. The insulation must be kept clean and dry. Oil and dirt in the insulation are as much out of place as grit or sand in a cylinder or bearing. In a direct-connected unit, oil may splash from the driving machine or work along the shaft to the insulation and cause a burn-out unless the attendant provides the necessary protection.

Before installing or opening a machine, read all of the following instructions carefully, making note of the parts and points to be observed. On account of divergence in construction of the different types, it has been impracticable to arrange all information on any one line of machines in consecutive order.

MECHANICAL RE-DETERMINATION OF BRUSH POSITION
On Fabricated Type D-C. Brush Riggings

(See Fig. 9, Page 9)

The following is the mechanical method for checking the factory brush position:

With a convenient constant radius, using the two center punch marks, surrounded with circle marks on the front edge of the frame as centers, scribe two arcs to intersect on the front end of the commutator bars near the commutator surface. Draw through this intersection a radial line to the commutator surface. This point on the commutator surface is the center position of the ARC of the brush fit on the commutator; that is, it is the factory brush position. This point may or may not be the electrical neutral position, as machines are shipped with the brushes in a position to give the best operation both in regards to commutation and other operating characteristics. The position of one row of brushes is thus established; and the other rows of brushes can be spaced with reference to the first row of brushes. The brush spacing between all rows of brushes should be accurate within $\frac{1}{32}$ inch.

Due to the angularity of the contact of the brush on the commutator surface, the center position of the ARC of the brush fit on the commutator does not coincide with the mechanical center line of the brush.

Westinghouse

Direct-Current Generators and Motors

General Information

Types of Construction—Westinghouse standard direct-current generators and motors are divided into the following types:

(1) *Belt-Driven, self-contained type,* having two or three bearings, shaft and pulley.

(2) *Coupled, self-contained type,* having two bearings and shaft arranged for direct connection to the prime mover, whether steam, internal-combustion, or hydraulic, if a generator; or to the element to be driven, if a motor. The frames may or may not be provided with a bedplate.

(3) *Engine type* consisting of a complete field and armature without bearings or shaft, the armature to be mounted on the extended shaft of the prime mover, if a generator, or on the extended shaft of the element to be driven by motor.

(4) Engine-type machines of the larger sizes are not as a rule provided with bedplates. In place of one large bedplate, two smaller supporting pieces, known as soleplates are supplied. These plates are grouted into the foundation on each side and furnished with a finished seat for the supporting lugs of the field frame.

(5) *Turbo-Generators*—These machines are built for steam turbine drive. They differ from the ordinary engine-type machines mainly in the mechanical feature required for the higher rotative speeds at which they operate.

(6) *Turbine Reduction Gear Generators*—These machines are essentially of the engine type with a forged, flanged shaft which couples directly to the gear shaft. The bearings and bedplate are usually supplied by the turbine builder.

Output—The output of a generator in kilowatts may be obtained by multiplying the current in amperes by the e.m.f. in volts and dividing by 1000. To obtain the horsepower output of a motor, multiply the current in amperes by the applied e.m.f. in volts and multiply this product by the efficiency and divide by 746.

$$\text{Kilowatts} = \frac{\text{Volts x Amperes}}{1000}$$

$$\text{Horsepower} = \frac{\text{Volts x Amperes}}{746} \text{ efficiency.}$$

Windings—Depending upon the character of field winding employed, a direct-current machine is classified under one of the following three general groups:

1—Shunt wound.
2—Series wound.
3—Compound wound.

Shunt-Wound Generator—The field winding of a shunt-wound generator is composed of a large number of turns of wire or strap of comparatively high resistance, which is connected directly to the armature terminals, forming, in parallel with the main circuit, a shunt circuit through which only a small percentage of the total current flows.

The regulation characteristics of a shunt-wound machine are such that the voltage is a maximum at no load, and drops as the load increases unless regulated by the manipulation of a rheostat in the field circuit.

Series-Wound Generator—The field winding of a series-wound generator is composed of a heavy wire or strap connected in series with the armature and external circuit. With this type of machine the total current delivered flows through the field winding and the voltage varies directly with the load. The greater the load the higher the voltage. Generally, a slight load is required to make these machines pick up voltage therefor series generators are very infrequently used.

Compound-Wound Generator—A compound-wound machine has both shunt and series windings. It may be generally assumed that the shunt field is so designed that on open circuit, the series field being idle, the machine will generate the desired line voltage. The result of applying load would, as noted under "Shunt Generator", tend to lower the terminal voltage; but it is here that the utility of the compound winding becomes apparent. The series coils reinforce the shunt field in direct proportion to the increase of load and thus hold the terminal voltage approximately constant, balancing the drop due to increased copper loss and armature reaction at the heavier loads.

In order to allow some variation and permit adjustments to suit operating conditions additional hand regulation is provided in the form of a rheostat in the shunt-field circuit.

It is desirable that compound wound generators be supplied with flat compounding, that is, the same voltage at no load and at full load current, as better division of load between generators in parallel is thus secured.

In some cases the compound winding is connected in reverse, so as to buck the shunt field action. In this case, the machine is called a differentially-compound generator and the voltage droops considerably more than that of a shunt-wound generator.

Long and Short Shunt—When the shunt field winding of a compound-wound generator is connected across the outside terminals of the machine, shunting both the series field and armature windings, it is known as long shunt.

When the shunt field is connected inside the series field it is known as a short shunt. This is the more common practice. The voltage applied to the shunt being higher than it would otherwise be by the amount of the drop through the series winding. This assists somewhat in the regulation.

Three-Wire Generators—Any of the above types can be made into a three-wire generator. In this modification equidistant taps are made in the armature winding and carried to collector rings at the end of the armature. The rings are connected through sliding brushes to a choke or balance coil. The middle point of the coil constitutes the neutral point to which the third or neutral wire of the system is connected. A practically constant voltage is maintained between the neutral and outside wires which is one-half the generator voltage. See Fig. 1. Two collector rings and one balance coil are used. Three-wire operation requires that one-half the commutating field and series field windings, if any, be connected on each side of the line in order to maintain the same total field strength under unbalanced load.

Series Motors—Series motors are variable speed machines particularly adapted to a few special uses, such as railway and crane service, but are not extensively employed in the field of work to which this book is devoted. The characteristic features of a series motor are its great torque at starting and low running speeds under heavy loads. A series motor should always be positively connected to a load, as it has a very high run-away speed at no-load.

Compound-Wound Motors—For some special classes of service, in which it is necessary to start under heavy load and later operate at approximately constant speed, a series winding is added to assist the shunt field at the low speed points.

As in the case of the compound generator, a compound motor combines the characteristics of both shunt and series motors. The series winding gives a drooping speed regulation to the motor and increases the starting torque.

Shunt Motors—This is by far the most common type of winding, and is generally applied to motors designed for operation at constant speed under constant or varying loads. Nearly all commercial applications, particularly those of large capacity, require this type of motor. When necessary, considerable speed variation can usually be secured by means of a rheostat in the field circuit, increased resistance resulting in an increased speed. Practically all so-called 'shunt' motors have a slight series field winding, usually known as a stabilizing winding, to maintain stability under load.

Installation

General Precautions—Upon the receipt of the cases containing the machine or its parts, place them in a dry and sheltered position. Do not open them, and disturb them as little as possible, until everything is finally ready for assembling.

It is easily possible by rough handling or careless use of bars or hooks to do more damage to a machine before or during erection than it would receive in years of regular service. Bear in mind that the armature is liable to damage, since its own weight is sufficient to crush the winding, if it is lowered on or swung against a projection.

Do not open cases containing the armature or field coils until their contents are about as warm as the room, otherwise they will "sweat".

The safe rule is to open all such cases during the cool part of the day.

Location—It is very important that the location be wisely chosen, due regard being paid to the rules of the National Board of Fire Underwriters and to local regulations. The following considerations should also be carefully observed:

(1) The machine should be located in a cool, dry place, well ventilated and not exposed to moisture. Remember that the room temperature is added to that developed in the machine. All fittings below the frame must be absolutely tight with no possibility of moisture or escaping steam reaching the windings from that direction.

(2) The machine should not be exposed to dirt from coal handling or other operations.

(3) A direct-current machine must never be placed in a room where any hazardous process is carried on, or in a place where it will be exposed to inflammable gases or flying chips, sawdust or other combustible material.

(4) The machine should be located so as to receive proper ventilation. This is important and means that the air circulation in the room must be such as to carry away the heated air and

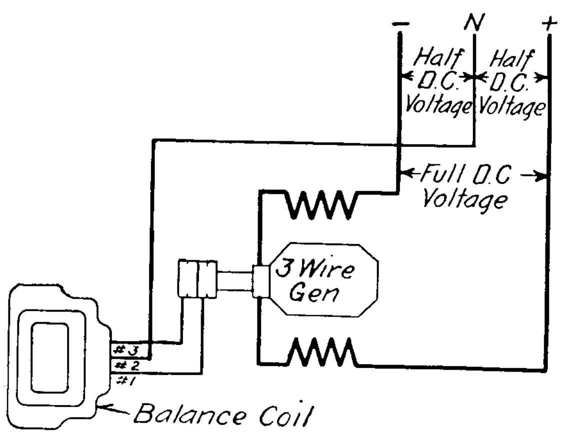


Fig. 1—Diagram Showing Connections of Balance Coils for Three-Wire D-C. Generators, 125-250 Volts

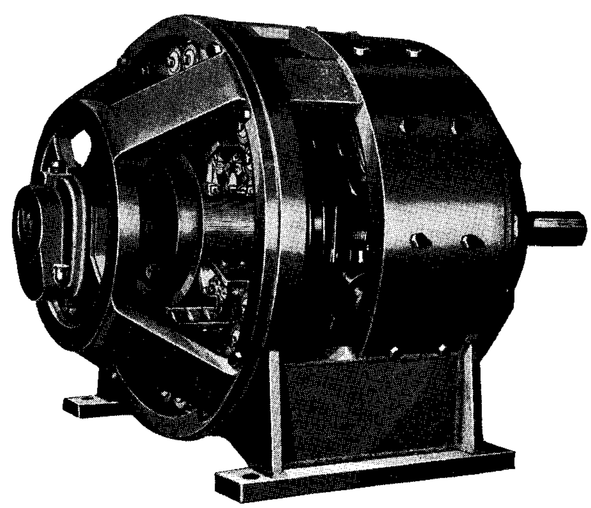


Fig. 2—Standard Type SK Fabricated Motor-Generator

supply cool air to the machine. To provide this it may be advisable in some cases to put in ducts that will bring air from outside of the building.

(5) The machine should be so located that it will be easily accessible for observation, inspection, oiling and cleaning.

(6) Belt-driven machines should have proper distance between belt centers.

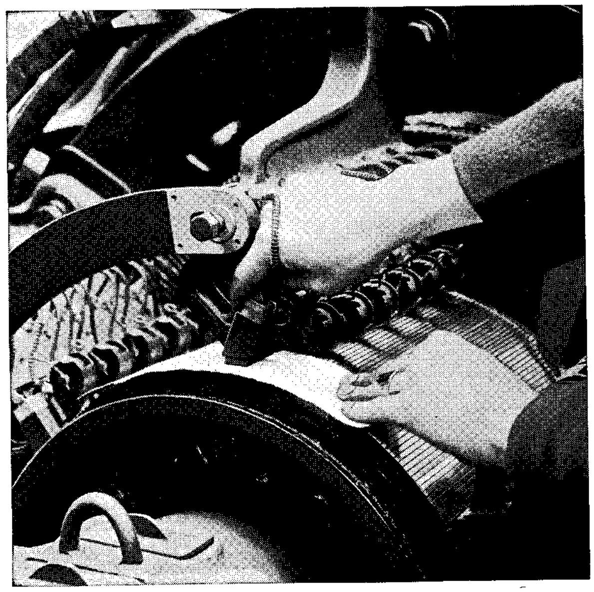


FIG. 3—GRINDING BRUSHES

Foundations—Machines not exceeding 50 kilowatts capacity may be supported by timber bases, but larger units require solid masonary or concrete foundations, to which they should be secured by foundation bolts. These bolts must be accurately spaced, the approved method of location being to construct a light wood template or frame with the bolt holes carefully bored to dimensions given on the blue print of the generator base. It is advisable to have these bolts, surrounded by iron pipes of proper length and with inside diameter somewhat larger than bolts, set in the foundation with the openings in the masonry to allow access to the nuts at their lower ends in case renewals become necessary. The slight flexibility of position permitted by this pipe construction is often of great convenience on the final lining up of the bedplate.

Be sure that the foundation is carried down to a solid bottom, or is made of sufficient area to prevent sinking or displacement under the full load it is expected to support.

A competent engineer who is familiar with local conditions should lay out this part of the work.

Care should be taken that all pits in the concrete are properly drained and that passages remaining for piping and wiring are easily accessible and so laid out that the work of installing and connecting up will be simplified in every possible way.

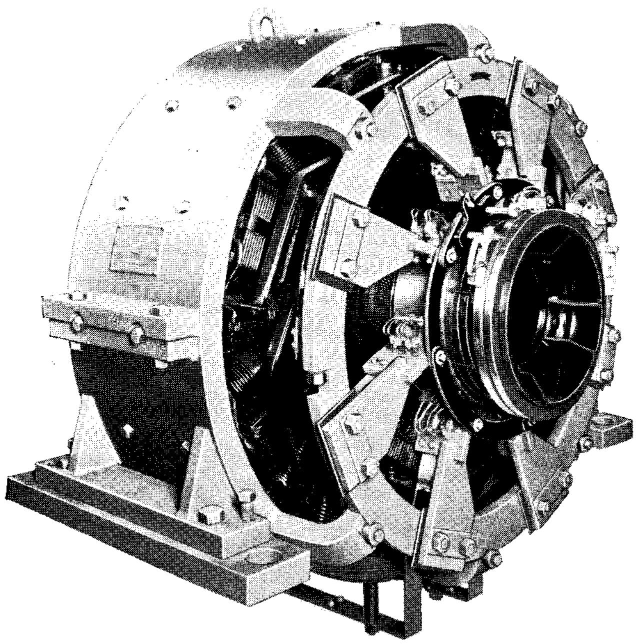


FIG. 4—COMMUTATOR END VIEW OF ENGINE TYPE QS GENERATOR, SHOWING COLLECTOR RINGS FOR 3-WIRE SERVICE

Erection of Belted Generators and Motors—(1) Set the lower half of the frame and rocker ring in position. Level and insert the bearings, if they are separately shipped. Inspect the bearings and oil reservoirs carefully to be sure they are clean and free from dirt.

(2) After covering the journals with a film of oil, lower the rotating part into the bearings. Fill the bearings with oil to the proper level, place the bearing caps in position and screw down the cap bolts lightly.

(3) Clean the contact surface of both halves of the frame. Set the upper half in position and secure to the lower half by the bolts and feather keys. Swing the upper half of the rocker ring into place and, after securing it, see that it moves easily in its seat.

(4) Connect up the armature and field leads. Adjust the brushholders properly with respect to the commutator and see that the brushes are set on the factory brush position by following out the instructions in regard to brush position as given on page 2. After inserting the carbon brushes they should be ground to a perfect seat on the commutator, using sandpaper only. (See Fig. 3.)

The pressure on all brushes should be the same, 2 to 2½ pounds per square inch of cross sectional area of brush.

(5) Accurately align the shaft with the driving or driven shaft, with the center lines of pulleys directly opposite. Tighten up the foundation bolts. Place the belt in position and run slowly. If the shafts are parallel, but the pulleys not directly opposite, the belt will run to one side of the larger pulley. If the pulleys are opposite but the shafts not parallel, it will run to one side of the smaller pulley.

(6) After final adjustment, set the foundation bolts up hard.

(7) Connect to switchboard.

Some of the smaller generators are shipped completely assembled and need only to be set upon their foundations, leveled and lined up before making connections.

Erection of Coupled Generators and Motors—Proceed as in sections 1, 2, 3 and 4 of the preceding instructions.

(5) Align the generator shaft with the driving shaft and mount the coupling.

(6) Connect the couplings and run slowly; then secure the machine permanently to its foundation.

Erection of Engine-Type Machines—

(1) Set the soleplates, if any, in place and level up to proper position; i.e., to such a height as will allow room for one-half of the liners allowed for adjustment under the frame when the air-gap is correct.

(2) Place the lower half of the field frame and rocker ring in position.

(3) With machines of large size, the armature must be pressed upon the shaft at point of installation, if this has not been done at the factory.

The shaft is turned accurately to a certain gauge and the hub is bored out to a similar gauge several thousandths of an inch smaller in order to secure a press fit. Before attempting to force the armature on its shaft, inspect the surfaces to be fitted as they may have received injury during transportation. File down any roughness of this sort and smooth with emery cloth.

See that the key has a good bearing on its sides and clears on top about $\frac{1}{32}$ of an inch.

Before proceeding further with the operation, the surfaces on the shaft and the interior of hub finished for the fit should be painted with a mixture of white lead and engine oil to prevent cutting the shaft.

The pressure required to force the armature on, varies with the temperature, condition of surface, and quality of the metal to such an extent as to make it practically impossible to estimate its value with any degree of accuracy. It is generally safe to assume that from 100 to 200 tons pressure will be required.

For forcing a large armature on its shaft, a hydraulic press is preferable. When this cannot be secured, make two yokes out of I-beams. Place one of these across the rear of the armature so as to press on the end of the armature spider, and one at the end of the shaft, and draw the armature in place by means of two bolts which pass through the yokes and spider close to the shaft. Care should be taken to tighten up evenly on the bolts, otherwise the spider will twist and bind on the shaft. Once started, this operation should be carried to completion as quickly as possible, as, if the armature is allowed to set several hours when only part way on the shaft, it may require from 25 to 50 per cent more pressure than was previously used to start it again.

Do not mar or scratch the shaft, as any roughness may cut the bearings and cause them to run hot. A large armature which must be pressed on the shaft in the station should be supported when possible on the spokes of the spider by passing heavy timbers through the spider and blocking up to them at each end. When this is impossible, it should be set in a cradle cut out of heavy timber to fit, and lined with excelsior or waste, so that the weight will be evenly distributed over a large area of the core. This cradle should be made narrower than the core in order not to injure the winding. An armature so supported should be braced on both sides.

After the armature has been pressed upon the shaft, it should be carefully lifted in a sling and lowered into its bearings.

Caution—Never support the armature wholly or in part by the commutator, either when raised by blocking or when held by a rope sling. Lift it by a rope sling about the shaft, taking great care that the ropes do not touch the windings at the back end of the armature. Do not allow workmen to stand on the commutator.

(4) Adjust the frame in position. shifting it in a direction parallel with the shaft until its center line (half-way between the edges of the laminated iron) is directly opposite the center of the rotating part (half-way between the endplates which hold the laminations of the core). Place the top half of the frame in position, mount the upper part of the rocker ring and check adjustments to see if they are still correct.

(5) If mounted on soleplates, tighten the soleplate bolts and cement the soleplates to the foundation, using a mixture of one part of Portland cement and two parts of sand, or half cement and half sand; either will give good results. First mix the cement and sand dry and then add water until a very thin solution is obtained. Construct a dam around the bedplate and pour this solution under it continuing the process until the cement stands about half an inch above the bottom of the soleplates. The entire operation of mixing and pouring the cement should be carried on without interruption and as rapidly as possible until completed, otherwise the cement first poured under the bedplate may partially set and prevent that poured later from flowing freely to all parts. When the cement has sufficiently hardened, remove the surplus from the outside and smooth up the joint under the soleplates.

(6) Adjustment of the air-gap—In setting up any machine in which the bearings are independent of the frame, great care must be exercised in the adjustment of the air-gap between the armature core and pole faces, as any inequality in this gap may cause unnecessary friction and heating of the bearings and unequal heating of the armature iron. Adjust the air-gap horizontally by shifting the frame, and vertically by means of thin sheet steel liners between the bedplate and the yoke. During this operation gauge the gap at different points on the front and back of the machine by inserting thin feelers in the air gap and measuring the thickness of the stack of feelers.

(7) Connect up the field and armature leads. Insert the brushes in their holders, grinding them in with sandpaper. See Fig. 3. See that the brushes move freely in the holders and are held under an equal and moderate pressure. Two to two and a half pounds per square inch of cross sectional area is a normal pressure. At the same time check to see that the brush alignment

is correct, that is, that the edges of the brushes are parallel to the commutator bars, and that the brushes are accurately spaced and the brushholders within $\frac{1}{16}$ to ⅛ inch of the commutator surface. Connect the machine to the switchboard. (For further information see diagrams pages 18 to 20 inclusive.)

Drying Out—If a generator has been exposed to dampness, before being started in regular service it should be run with its armature short-circuited beyond the ammeters and with the field current adjusted so as to raise temperature to about 70°C. The current should then be lowered and raised by means of the field adjustment until the coils become thoroughly dry. The temperature should not be allowed to drop to that of the surrounding atmosphere, as the moisture would then again be condensed on the coils, and the machine brought to the same condition as at the start.

There is always danger of overheating the windings of a machine when drying them with current, as the inner parts, which cannot quickly dissipate the heat generated in them and which cannot be examined, may get dangerously hot, while the more exposed and more easily cooled portions are still at a comparatively moderate temperature. The temperature of the hottest part accessible should always be observed while the machine is being dried out in this way and should not be allowed to exceed 80 degrees Centrigrade total temperature. It may require several hours or even days to thoroughly dry out the machine, especially if it is of large capacity. Large field coils dry very slowly. Insulation is more easily injured by overheating when damp than when dry.

Insulation Test—It sometimes happens that the insulation of a machine is mechanically injured or exposed to moisture after the factory test but previous to erection. For this reason insulation tests should be made before the machine is run.

The higher the resistance, the better the general condition of the insulating material. The insulation resistance of the field will be much higher in proportion to the e.m.f. or the exciting current than of the armature and will in general give little trouble. Since large armatures have much greater areas of insulation, their insulation resistance will be proportionately lower than that of small machines. Even though the material is in exactly the same condition, the insulation resistance of any machine will be much lower when hot than when cool, especially when the machine is rapidly heated. The only feasible way of increasing the insulation resistance when the machine is complete is by "drying out". Armature winding and field coils are dried out by heat; baking in an oven is to be preferred but is often impracticable. They are usually heated by the passage of current. In the case of the armature this may be accomplished by short-circuiting the leads and running the generator with a low field excitation, just sufficient to produce the proper current.

In making the insulation resistance measurements a 500-volt direct-current circuit and a 500-volt direct-current voltmeter may be conveniently used. The method of making a measurement is to first read the voltage of the line, then to connect the resistance to be measured in series with the voltmeter and take a second reading.

The measured resistance can be readily calculated by using the following formula and the method of connecting the apparatus shown in the diagram Fig. 6.

$$R = \frac{r\,(V\text{-}v)}{v}$$

V = voltage of the line.

v = voltage reading with insulation in series with voltmeter.

r = resistance of voltmeter in ohms (generally marked on label inside the instrument cover).

R = resistance of insulation.

Voltmeters having a resistance of one megohm are now made for this purpose so that, if one of these instruments is used, the calculation is somewhat simplified, since r = 1 and the above formula becomes

$$R = \frac{V - v}{v} = \frac{V}{v} - 1 \text{ megohms.}$$

If a grounded circuit is used in making this measurement care must be taken to connect the grounded side of the line to the frame of the machine to be measured, and the voltmeter between the windings and the other side of the circuit.

Breakdown Test—A high-voltage or breakdown test is useful in determining the strength of the insulation of the machine. It is made by subjecting the insulation to an e.m.f. greater than it will have to stand in actual service. As this test is in the nature of an overstrain, it must be applied with great caution. Such tests are always made

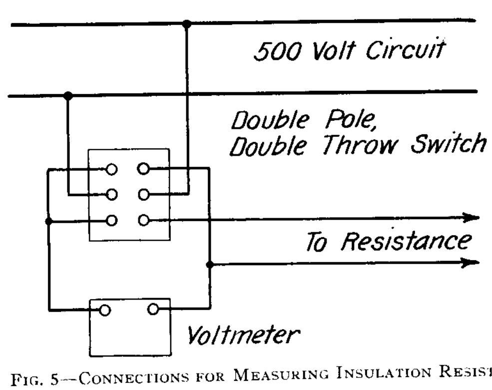


Fig. 5—Connections for Measuring Insulation Resistance

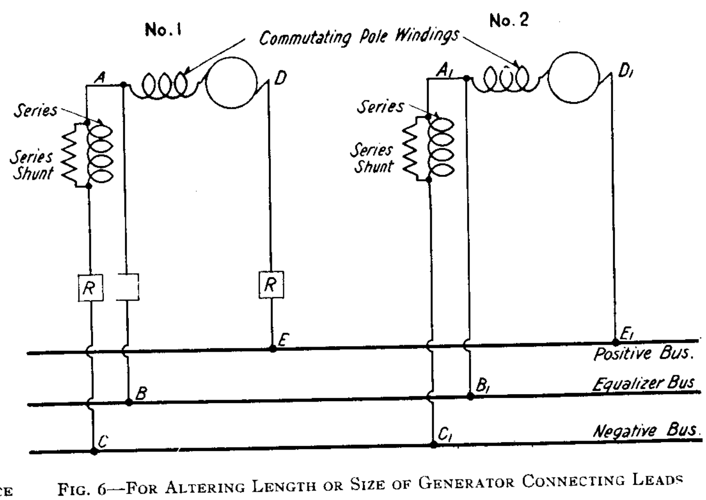


Fig. 6—For Altering Length or Size of Generator Connecting Leads

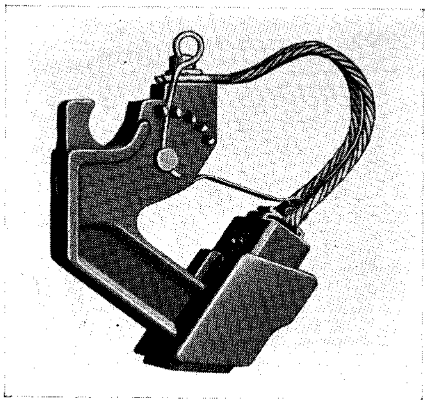


Fig. 7—D-C. Brushholder for QS and QH Generators and Motors

in the factory and rarely need to be repeated. However, when they must be made, it is well to remember that the insulation is more easily broken down when hot than when cold and that the test should not be made immediately after the machine is started the first time but after it has run hot for some hours and has a chance to dry out. Tests of this character should not be made when the insulation resistance is low.

Large machines, when tested at high voltage, require a considerable output from the raising transformer, as a heavy charging current is taken by the machine. The transformer capacity required for testing varies with the square of the voltage of the test, with the frequency of the circuit, and with the static capacity of the apparatus under test. A 5-kilowatt transformer has sufficient output for testing machines up to 500 kilowatts at a testing e.m.f. of 6000 volts.

When making a high-voltage test, the **low-voltage circuit** should always be closed or opened to throw the e.m.f. on or off.

The severity of the test depends to a marked degree upon the time the e.m.f. is applied. All breakdown tests are supposed to be applied for not more than one minute, as long continued test is liable to permanently injure the insulation even if no immediate fault is developed.

Insulation of Frames—The desirability of insulating the frame from the ground is an open question, and must be decided upon by the merits of the case. As a matter of fact, frames of machines up to 700 volts are seldom insulated; it is well, however, to keep in mind the following points.

Broadly speaking, the strain on the insulation of the windings is decreased and the danger to the attendant increased by insulating the frame of the machine from the ground. There is also likelihood of flashing to ground with high-voltage machines.

If the frame is to be insulated from the ground the foundation can be capped with a stout wooden frame bolted to the masonry, care being taken that the bolts are so placed that they do not make electrical contact with the bolts which secure the machine base to the wooden cap. This wooden cap may be covered with some waterproof insulating paint or compound. Porcelain insulators set in the concrete of the foundation have also been used. In any case, an insulating platform should extend around the machine of sufficient width so that the attendant must mount it before he can touch part of the frame.

Direct-connected units necessarily have their rotating parts grounded through the driving machine and piping. The stationary parts might be insulated but it is difficult to accomplish this and at the same time secure the machine firmly to the foundation.

Connection for Parallel Operation—*Parallel operation of direct-current generators is effected in a comparatively easy manner if machines are of the same make and voltage or are designed with similar electrical characteristics. If they are shunt-wound machines, no connections other than main leads are required as the inherent regulation characteristics are such as to insure against one generator taking all the load and operating inverted, the other machines that are in parallel with it. However, division of load between generators in parallel must be effected by hand manipulation of field rheostats, if the inherent division is not close enough. If they are compound-wound machines, the addition of equalizer connections between the machines is required. If the generators have different compounding ratios, it will be necessary to change adjustments so that all machines have the same inherent regulation; i.e., with shunt field adjusted by rheostat for same voltage at no load, the compounding is such as to produce the same voltage on all at full load. The way to determine if all machines have the same regulation is to test them individually. The amount of compounding may be changed after installation by changing the amount of current shunted from the series field. As far as parallel operation is concerned, it is much better to have all generators flat compounded or even with a voltage regulation that droops slightly with load. The shunt field current is adjusted to give the desired voltage at no load, then the shunt across the series field is adjusted until the desired full load voltage is obtained.

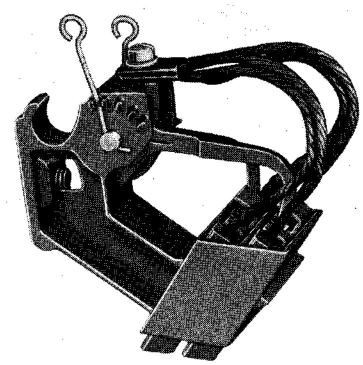


Fig. 8—D-C. Double Brushholder for QS and QH Generators and Motors

Equalizer—An equalizer, or equalizer connection, connects two or more generators operating in parallel at a point where the armature and series field leads join, thus placing the armatures in multiple and the series windings in multiple, in order that the load may be divided between the generators in proportion to their capacities. The arrangement of connections is shown in the diagram, (Fig. 6).

The object of the equalizer, as the name implies, is to divide the total load between the machines according to their capacity. Consider, for example, two compound-wound machines operating in parallel without an equalizer. If, for some reason, there is a slight increase in speed of one machine, it would take more than its share of load; and the increased current flowing through the series field would strengthen the magnetism, raise the voltage, and cause the machine to take a still greater

*See diagrams on pages 18 and 19.

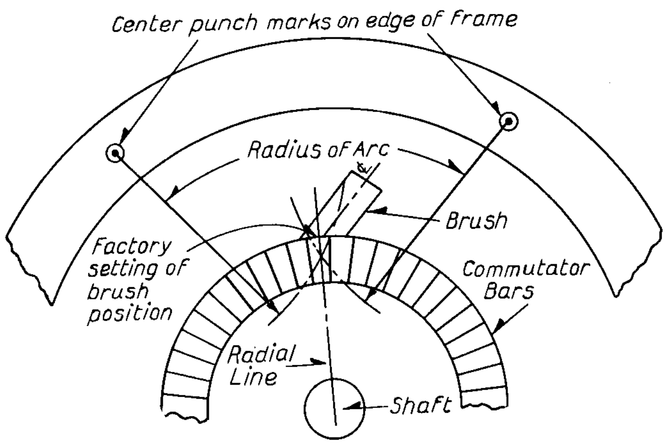


FIG. 9—TEMPLET IN POSITION FOR SETTING BRUSHHOLDER

amount until it carried the entire load. When equalizers are used, the current flowing through each series coil is proportional to the resistance and is independent of the load on any machine; consequently an increase of voltage on one machine builds up the voltage of the other at the same time, so that the first machine cannot take all the load, but will continue to share it in proper proportion with the other generators.

Series Shunts—A series shunt consists of a low resistance connection across the terminals of the series field, by means of which the compounding effect of the series winding may be regulated by shunting more or less of the armature current past the series coils. It may be in the form of grids, on large machines, or of ribbon resistors. In the latter case it is usually insulated and folded so as to take up but a small amount of space.

Connecting Leads—If generators are of the same size and make, the only feature requiring special attention in connecting to the switchboard is to see that all the cables which lead from the various machines to the bus-bars are of equal resistance. This means that **if the machines are at different distances from the switchboard, different sizes of cables should be used, or resistance inserted in the low resistance leads, to equalize the voltage drops in these circuits.**

If generators differ in design or size, the matter requires more attention. In this case the difference in potential or drop in voltage between the terminals of the machine and the bus-bars to which they are connected should be exactly the same for every generator when each is carrying its proper share of the load. To secure the best results, the total drop between generator terminals and switchboard must not only be the same at equal loads, but the drop in corresponding sections of the connecting cables of the different machines should also be equal; i.e., the drop in the positive lead from any one generator at full load should equal the drop in each of the other positive leads when carrying full load. The same condition should be secured in the negative leads, in the equalizer connections and in the series field windings. It may be necessary in achieving the desired results to alter the length or size of connecting cables, and occasionally additional resistance is required.

The diagram in Fig. 6 will indicate how this is to be done.

To meet the conditions for parallel operation the volts drop through the leads D_1 E_1 and DE must be equal, and the drop from A_1 to C_1 including series winding must be equal to that from A to C including series winding. R shows resistance added, if required. While the diagram is made for two machines, it, of course, applies to any number.

In ground return systems, such as are constantly employed with street railways, it simplifies the connections

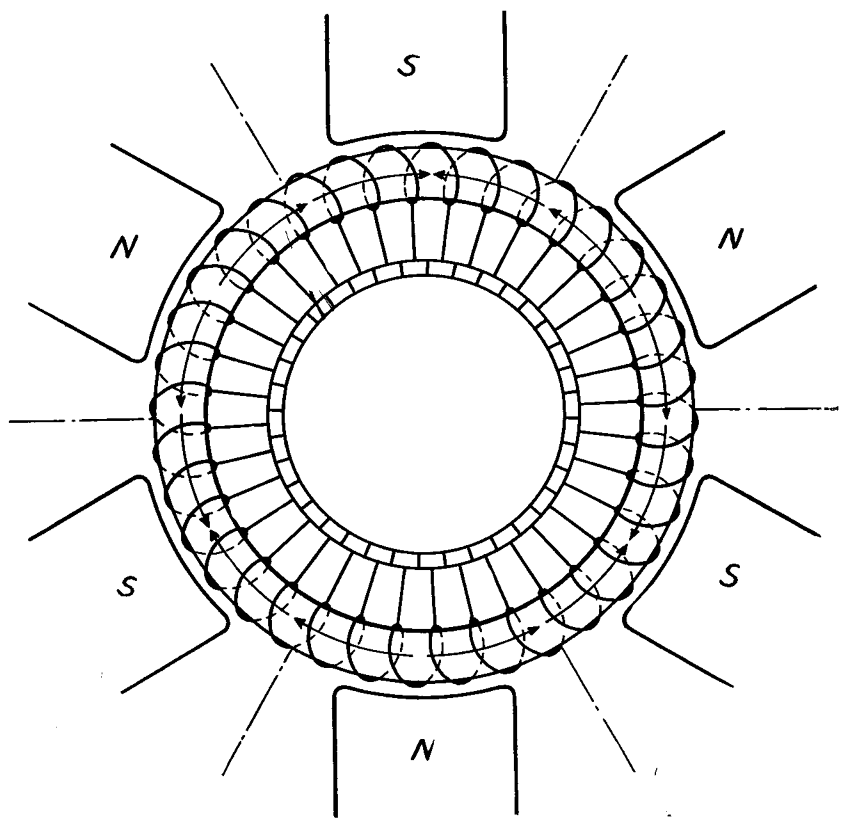


FIG. 10—RING WOUND ARMATURE
ARROWS INDICATE VOLTAGE INDUCED WHEN FIELD IS OPENED

considerably to adopt the single bus system shown in Fig. 21.

The equalizer lead must have as little resistance as is practicable, and for this reason it is the usual practice to make the equalizer leads the same size as the main leads.

Brush Position—When the brush position on a commutating-pole machine has once been properly fixed, no shifting is afterward required or should be made, and most commutating-pole generators are shipped without any brush shifting device. An arrangement for securely clamping the brushholder ring to the field frame is provided.

Adjusting the Brush Position—In commutating-pole machines accurate adjustment of the brush position is necessary. The correct brush position is located at the factory during test.

If the brushes are given a backward lead on a commutating-pole generator, the machine will over-compound and will not commutate properly.

With a forward lead of the brushes, a generator will under-compound and will not commutate properly. In a motor a backward lead of the brushes will increase the speed and a forward lead will decrease it. The commutating poles are so connected that in a generator a "north" commutating pole comes before a north main pole; that is, for a certain direction of rotation an armature conductor will come first under the commutating pole. In a motor the north commutating pole comes back of a north main pole; that is, an armature conductor will come first under a main pole.

On a three-wire generator, connections are so made that one-half of the commutating pole winding is in the positive side and the other half is in the negative side. This insures proper action of the commutating poles at unbalanced load.

Locating Brush Position—Where it is necessary for any reason to locate the electrical neutral position on commutating-pole machines in the field, the following methods can be used:

Mechanical Method—When it is impossible to set the brushes by the "kick" method, a mechanical method can be used. The proper position of the brushes, on most machines, is in a plane which passes through the centers of two diametrically opposite main pole pieces. This position can be approximately located on machines, the armature coil throw of which is exactly one pole pitch, by tracing the lead from a conductor under the center of the commutating pole to the commutator bar. As many machines are made with chorded windings, this method can only be used as approximate and the brushes should be set by actual trial by observing the commutation under load with the brushes in different positions.

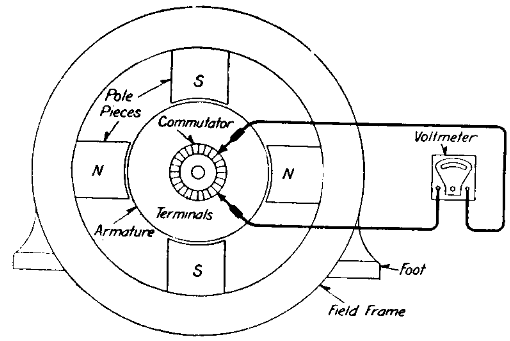


FIG. 11—FINDING ELECTRICAL NEUTRALS WITH VOLTMETER

Electrical or "Kick" Method—The electrical neutral for brushes may be correctly and simply located if due care is exercised.

With all the brushes raised from the commutator and the machine standing still, if the shunt field be excited to about one-half of its normal strength and the field current suddenly broken, voltages will be induced in the armature conductors by a transformer action. Consideration of these voltages in conjunction with the diagram in Fig. 10 will show that the maximum voltages are produced in those conductors located in the interpolar space (between the main poles) and that the minimum voltages are produced in those conductors located nearest to the centers of the main poles. It will also be found that the induced voltages in conductors located at equal distance to the right and left of the main pole centers are equal in magnitude and opposite in direction.

Hence, if the terminals of a low-reading voltmeter (say five volts) be connected to two commutator bars on opposite sides of the center line of a main pole (Fig. 11) and exactly half way between the center lines of two main poles, it will show no deflection when the field current is broken, because there will be equal fluxes in opposite directions through equal numbers of turns. The spacing of these commutator bars is evidently the correct distance between brushes on adjacent brush arms.

In Fig. 10 a ring-wound armature is shown for simplicity. The leads come straight out to the commutator bars and the neutral points, in this case, will be midway between the main poles. In actual practice, the armature conductor, which lies in the exact neutral zone on the surface of the armature, leads to a commutator bar located approximately under the center of a main pole, hence the electrical neutral on the commutator will be found approximately in line with the main pole centers.

To find the electrical neutrals in practice, two pilot brushes are made of wood or fibre to fit the regular brushholders and each brush carries in its center a piece of copper fitted for making line contact with the commutator and for connection to the voltmeter leads.

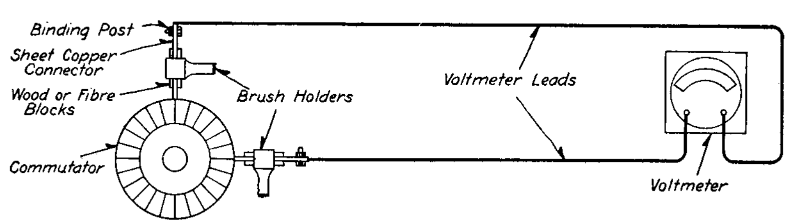


FIG. 12—SHOWING CONSTRUCTION OF PILOT BRUSHES

Fig. 11. These two brushes are put into regular brushholders located on adjacent brush arms and connected to the terminals of the voltmeter. Fig. 12. The holders and brushes are then shifted slightly forward or backward as necessary until breaking the field current occasions no deflection on the voltmeters. It may also be necessary to move the rotor position slightly, so that the coil lying in a slot will be in the electrical neutral position.

This neutral point is noted and the pilot brushes are then similarly used in another pair of brushholders on adjacent arms and so on, all of the way around the commutator, noting whether each position proves to be a neutral point. The average of the positions of neutrals thus obtained gives the correct running location for the brushes.

If the armature winding is perfectly symmetrical and the commutator has an integral number of segments per pole, a position can be obtained where there will be no deflection of the voltmeter connected between adjacent neutral points when the field current is broken; but with two circuit armature windings extensively used in the smaller sizes of machines, it is impossible to have an integral number of commutator segments per pole. In such cases it is necessary to make a number of repeated trials and to so set the brushes that the sum of the voltmeter deflections obtained by taking readings all of the way around the commutator will be a minimum, the positive and negative signs of the readings being disregarded.

If no deflection occurs between brushes spaced from each other by an odd number of poles, and additional check on the electrical neutral is established. For example, in a 6-pole machine the pilot brushes may be placed in diametrically opposite holders and the neutral found as before described. This method has the advantage that by its use a point of no deflection or zero reading is obtainable where the number of commutator bars is divisible by two, as in many 6-pole machines.

Where double brushholders are used, the two pilot brushes should be inserted in corresponding boxes of double brushholders on adjacent arms, so that the point of these brushes will be exactly one pole pitch apart measured on the commutator periphery. After the neutral point is located and the brushes are in the double brushholders, the rocker ring will have to be shifted until the mid-point of the arc length, covered by the span of the two brushes on the commutator surface, corresponds to the neutral point, in order to locate the brushes on neutral.

The brush position as located by factory test may or may not be on the electrical neutral as the brushes are set on test and the machine shipped with them in a position to give the best operation, both in regards to commutation and other operating characteristics.

This being the case, it is best when the brush position has been once disturbed to re-locate the brushes so that they will be on the factory setting. This can be easily done as follows: With a convenient radius, using the two center punch marks, surrounded with circle marks on the front edge of the frame as centers, scribe two arcs to intersect on the front end of the commutator bars near the commutator surface. Draw through this intersection a radial line to the commutator surface. The point of intersection of this radial line on the commutator surface is the center position of the **arc** of the brush fit on the commutator. Figure 9 is a sketch showing how this is carried out.

Due to the angularity of the contact of the brush on the commutator surface, the mid-point of the length of arc of the brush fit on the commutator does not necessarily coincide with the intersection of a mechanical center line of the brush on this same arc. It is, therefore, necessary that the mid-point on the arc periphery of the brush contact fit be set on this factory setting point just obtained. The position of one row of brushes is thus located, and the other brushes can be spaced with reference to this first row of brushes. The brush spacing between all rows of brushes should be accurate to within $\frac{1}{32}''$. The best way to secure this spacing is to cut a narrow strip of tough paper exactly equal in length to the circumference of the commutator. This strip is then marked off into equal parts, corresponding to the number of poles, after which it is stretched around the commutator and the brushes spaced accordingly. This method gives far more accurate results than those obtained dependent upon the uniform spacing of the bars. The latter method, however, may be used as a rough check.

Operation

General Rules—(1) Leave all switches open when machine is not running.

(2) At all times keep the generator or motor clean and free from oil and dust, especially from copper or carbon dust. With high-voltage machines, a small accumulation of dust on the windings may be the cause of serious burnout. In stations of sufficient size to warrant the expense it is advisable to install an air pump for supplying compressed air with a piping system so distributed that a short section of hose will enable the attendant to reach all parts of the winding or any machine to blow out the dust. The pressure used in such service should not exceed 25 pounds per square inch, as a high pressure may lift the insulation wrappings on the windings and blow dust inside the coils. Always allow any accumulation of water in the pipes to be blown out before turning the air blast on the machine.

(3) Keep small pieces of iron and bolts and tools away from the frame. Any such fragments attracted to the pole of a field magnet may jam between the armature and pole and cause serious damage.

(4) Occasionally give the machine a thorough inspection. The higher the voltage of the generator or motor, the oftener this should be done.

Starting Generators—(1) See that the bearings are well supplied with oil and that the oil rings are free to turn. Inspect all connections for loose screws or wires.

(2) Start slowly. See that the oil rings are revolving properly.

(3) Turn in all resistance in the field rheostat, then bring the machine up to speed.

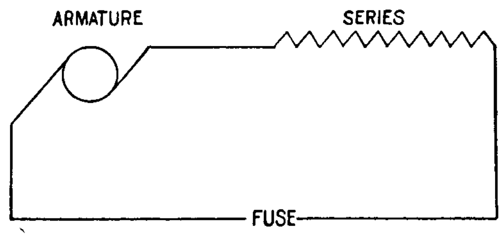


FIG. 13—SHOWING CONVENIENT METHOD OF MAKING A COMPOUND-WOUND GENERATOR PICK UP VOLTAGE

(4) Adjust the rheostat for the normal voltage of the generator.

(5) Throw on the load.

Causes of Insufficient Voltage—The following causes may prevent generators from developing their normal e.m.f.

The speed of the generator may be below normal.

The switchboard instruments may be incorrect and the voltage may be higher than that indicated or the current may be greater than is shown by the readings.

The series field may be reversed, or part of the shunt field reversed or short-circuited.

The brushes may be incorrectly set.

A part of the field rheostat or other unnecessary resistance may be in the field circuit.

Reversing Polarity—To change the polarity, if a generator keeps the same rotation, it is necessary to reverse the residual magnetism, which is done by exciting the shunt field momentarily in the opposite direction from some outside source.

Reversing Rotation—To change the rotation but not the polarity, it is necessary to reverse either the residual magnetism and field lead (both series and shunt) or the armature and commutating field leads. The simplest method, and the one recommended, is to reverse the leads to the armature and the leads to the commutating-pole winding. In all commutating-pole machines, it must be borne in mind that the direction of current in the armature and commutating-pole winding always bears the same relation to each other, and, if the armature current is reversed for any reason, the commutating-pole coils must be reversed.

No other changes are necessary in reversing Type QS or QH Generators.

To Parallel—To throw a machine on the line in "parallel" with machines already operating bring the machine up to normal speed.

With a voltmeter connected to its terminals, gradually bring up the voltage by cutting out resistance in the rheostat until approximately the voltage of the other machines is reached. Throw in the equalizer switch. Adjust voltage, if necessary. Throw in main switches. Adjust rheostat till generator takes its proportion of the load. The proper voltage to obtain before throwing a generator in parallel with others can be found by trial. It may vary slightly from line voltage depending on local conditions, regulations, etc.

Excitation—When starting up, a generator may fail to excite itself. This may occur even when the generator operated perfectly during the preceding run. It will generally be found that this trouble is caused by a loose connection or break in the field circuit by poor contact at the brushes due to a dirty commutator or perhaps to a fault in rheostat, or incorrect position of brushes. Examine all connections; try a temporarily increased pressure on the brushes; look for a broken or burnt-out resistance coil in the rheostat. An open circuit in the field winding may sometimes be traced with the aid of a magneto bell; but this is not an infallible test as some magnetos will not ring through a circuit of such high resistance as some field windings have even though it be intact. If no open circuit is found in the rheostat or in the field winding, the trouble is probably in the armature. But if it be found that nothing is wrong with the connections or the winding it may be necessary to excite the field from another generator or some other outside source. Calling the generator we desire to excite No. 1 and the other machine from which the current is drawn No. 2, the following procedure should be followed: Turn field rheostat on generator No. 1 to the all in position, open all switches and remove all brushes from generator No. 1, connect any one positive brushholder on generator No. 1 to any one positive brushholder on generator No. 2; also connect two negative brushholders together (it is desirable to complete the circuit through a switch having a fuse of about 15 amperes capacity in series). Close the switch. If the shunt winding of generator No. 1 is all right itsfield will show considerable magnetism. If possible, reduce the voltage of generator No. 2 before opening the exciting circuit; then break the connections. If this cannot be done throw in all the rheostat resistance of generator No. 1; then open the switch very slowly, lengthening out the arc which will be formed until it breaks.

A very simple means for getting a compound wound machine to pick up is to short-circuit it through a fuse having approximately the current capacity of the generator. (See Fig. 13.) If sufficient current to melt this fuse is not generated, it is evident that there is something wrong with the armature, either a short-circuit or an open circuit. If, however, the fuse has blown, make one more attempt to get the machine to excite itself. If it does not pick up, it is evident that something is wrong with the shunt winding or connections.

If a new machine refuses to excite and the connections seem to be all right, reverse the connections; i.e., connect the wire which leads from the positive brush to the negative brush and the wire which leads from the negative brush to the positive brush. If this charge of connections does no good, change back and locate the fault as previously advised.

To Shut Down Generator—(1) Reduce the load as much as possible by throwing in resistance with the field rheostat.

(2) Throw off the load when it is a minimum or zero, by opening the circuit-breaker, if one is used, otherwise open the feeder switches and finally the main generator switches.

(3) Shut down the driving machine.

(4) Wipe off all oil and dirt, clean the machine and put it in good order for the next run.

Starting Constant Speed Motors, Compound or Shunt—(1) See that bearings are well supplied with a good lubricating oil and that oil rings are free to turn. Inspect all connections for loose screws or wires.

(2) Make sure that the lever arm of the starting box or controller is in the "off" position.

(3) Close the main switch or circuit breaker.

(4) Close the field switch.

(5) Move lever arm of starting box or controller to the running position, pausing long enough on each notch to allow the motor to come up to the speed of that notch.

(6) If using a controller, throw the short-circuiting switch and move controller handle back to the starting position. If using a starting box, the lever arm should remain in the running position.

To Shut Down Constant-Speed Motors

(1) Open the main switch or circuit-breaker.

(2) After the motor has come to rest, see that the lever arm of the starting box has returned to its original position.

(3) Open the field switches.

(4) Clean the machine thoroughly and put in order for next run.

Starting Adjustable-Speed Motors—

(1) Examine shunt field rheostat and see that all resistance is cut out.

(2) Follow all directions given under "Constant Speed Motors."

(3) After motor is running on full-line voltage, gradually cut in resistance in the shunt field rheostat until the motor is up to the desired speed.

To Shut Down Adjustable-Speed Motors—(1) Gradually cut out the resistance in the shunt field rheostat until the machine is running on a full field.

(2) Follow directions given under "To Shut Down Constant Speed Motors."

Starting Series Motors—(1) Follow same instructions as those given for "Starting Constant Speed Motors," except there is no field switch to close.

To Shut Down Series Motors—(1) Open main switch or circuit-breaker.

(2) Examine machine carefully, wipe off all dirt or oil, and put in good shape for next run.

Opening of Feeder Circuits—If a line fuse blows or a circuit-breaker opens, first open the switch corresponding to that line, and then replace the fuse and close the breaker. The switch may now be closed again. If the circuit opens the second time, there is something wrong on the line—probably a short-circuit—and this should be corrected at once.

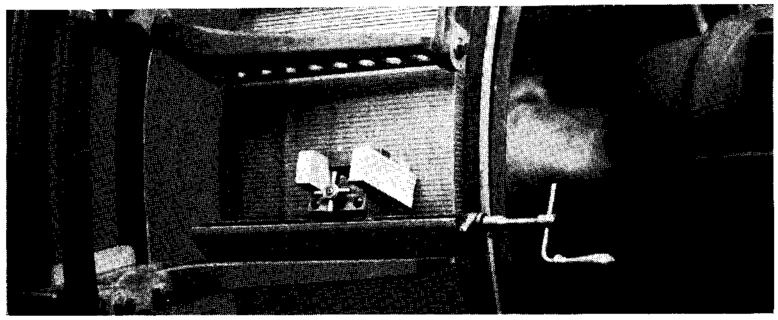


Fig. 14—Grinding Device for Truing Commutators

If for any reason, such as a short-circuit or a heavy overload on the line, the circuit-breakers or switches hold an arc when opened, such an arc should be extinguished if possible, by using dry sand, a supply of which should always be kept conveniently at hand. In case the arc cannot be extinguished in this manner, as a last resort, open the field circuit of the machine or shut the generator down entirely. When the arc forms on the machine or on the generator side of the breaker, a shut-down is generally imperative, but should not be made it it can possibly be avoided.

Brushes—The ends of all brushes should be fitted to the commutator so that they make good contact over their entire bearing face. This can be most easily accomplished after the brush-holders have been adjusted and the brushes inserted. Lift a set of brushes sufficiently to permit a sheet of sand-paper to be inserted. Draw the sand-paper in the direction of rotation under the brushes releasing the pressure as the paper is drawn back being careful to keep the ends of the paper as close to the commutator surface as possible and thus avoid rounding the edges of the brushes. It will be found by this mean a satisfactory contact is quickly secured, each set of brushes being similarly treated in turn. If the brushes are copper plated, their edges should be slightly sanded so that the copper does not come in contact with the commutator. (See Fig. 3).

Modern brushes have characteristics such that they do not require any oiling of the commutator for lubrication. Oil affects mica adversely and should not be allowed to come in contact with the mica of a commutator, as burnouts may result.

Machines which are subject to frequent reversals such as mill motors and street railway motors usually have the brushes set radially or with only a slight angle to the commutator surface. For non-reversing machines, the brushes are always set at an angle, usually against rotation. The proper angle varies depending on brush friction but usually lies between 15° and 35°.

Besides maintaining the brushes in the proper position as described on page 8 under "Installation", the following points should be observed:

Make frequent inspection to see that—

(1) Brushes are not sticking in holders.

(2) Pig tail shunts are properly attached to brushes and holders.

(3) Tension is changed as brush wears.

(4) Copper plating (when used) is cut back so it does not make contact with the commutator.

(5) Worn-out brushes are replaced before they reach their limit of travel and break contact with the commutator, or cut it due to metal of clip cutting into it.

(6) Remove any free copper picked up by the face of the brush. A much fuller treatise on brush selection and application is given in Instruction Book 5187 on "Selection, Application and Care of Brushes for Commutators and Slip Rings for Power Station Apparatus."

Commutator—The commutator is perhaps the most important feature of the whole machine in that it is most sensitive to abuse. Under normal conditions, it should require little attention beyond frequent inspection. The surface should always be kept smooth, and if, through extreme carelessness, neglect or accident, it becomes badly roughened, the armature should be removed and the commutator turned down in an engine lathe. Sometimes with large machines it is more convenient to rig

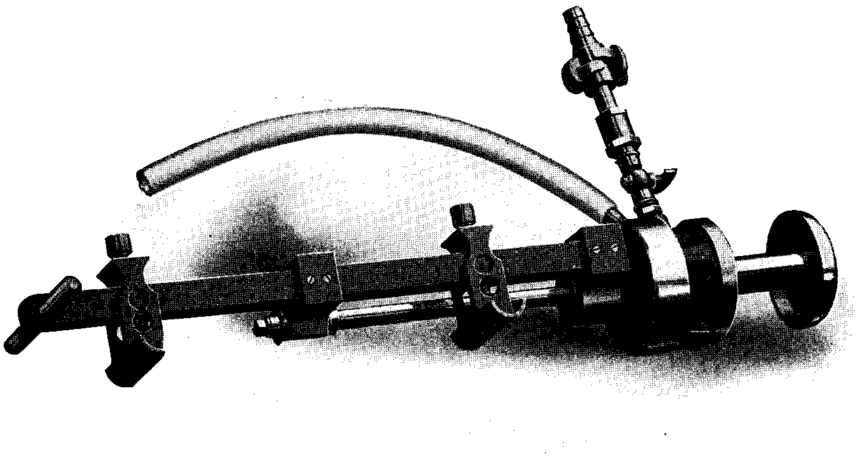


FIG. 15—SMALL PORTABLE TOOL FOR UNDERCUTTING MICA, ATTACHED TO AIR MOTOR

up a temporary truing device, leaving the armature in its own bearings and running it slowly either as a shunt motor or from a separate belted motor. Ordinarily, unless in very bad condition, it may be dressed down with a piece of sandstone conveniently mounted in a device especially designed for this purpose. (See Fig. 14.)

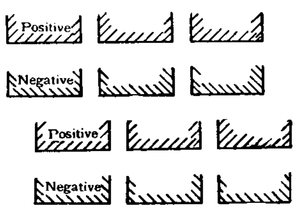


FIG. 16—CORRECT METHOD OF STAGGERING BRUSHES

This grinding device is mounted in one of the brushholder arms or brackets, the carbon holders being removed to accommodate it. The stone should be properly adjusted against the rotating commutator until a clean cutting effect is secured; the surface can then be finished with No. 00 sandpaper. Sometimes a little sandpapering is all that is necessary. **Emery cloth or paper should never be used for this purpose** on account of the continued abrasive action of the emery which becomes embedded in the copper bars and brushes. Even when sandpaper is used, the brushes should be raised and the commutator wiped clean with a piece of canvas. Cotton waste should never be used.

All commutators are thoroughly baked and tightened before leaving the factory, but if a bar should work loose it should be attended to promptly. The same may be said of flat spots or "flats" which will somtimes occur, due to a loose bar, unusually soft copper, or even to a severe flash or short-circuit.

Under normal conditions the commutator should become dark and highly polished after a few weeks' operation, and so remain unchanged for years.

Trouble is sometimes experienced from the burning out of mica insulation between segments. This is most commonly caused by allowing the mica to become oil soaked or by the bars loosening and thus allowing foreign conducting material to work its way between them. It is rarely, if ever, definitely traced to excessive voltage between bars. When this burning does occur it may be effectively stopped by scraping out the burned mica and filling the space with a solution of sodium silicate (water glass), or other suitable insulating cement.

Even with the most careful workmanship, high mica will sometimes develop on commutators which are not undercut, and start sparking, which burns away the copper and aggravates the difficulty. By prompt action serious damage can be prevented by cutting away the mica to a depth of one-thirty-second to one-sixteenth of an inch below the adjacent copper. A hack-saw blade held between suitable guides will serve the purpose of a cutter, but undercutting is much better done by a commutator slotting tool. The Westinghouse Company makes thses tools for either motor or air operation. (Fig. 15.) In most cases it is standard practice to undercut the mica before the machine is shipped.

Undercutting of Commutator Mica—For most satisfactory operation, that the mica between the bars of the commutators should be kept below the surface of the copper. In such cases, it is the practice to cut out the mica to a depth of about $\frac{1}{16}$ inch by a milling cutter or hand tool. This undercutting is always required in D-C.turbo-generators. When undercutting is necessary, it is done at the factory before the machine is shipped. In case the copper wears down in service, or is turned off in truing up, so that the mica becomes flush with the copper, it must be cut down again. A power-operated tool for doing this is shown in Fig. 15. A hack-saw blade can also be used. Care must be taken to remove the sharp corners on the bars and these corners should be well rounded.

Staggering Brushes—Staggering is done to give an even wear to the commutator and should be done in pairs of arms (not alternate arms), that is, one positive with one of its adjacent negative arms should be set, to the right or left of the initial pair $\frac{3}{8}$ inch or more. The third pair should trail the first pair; the fourth, the second, and so on. (See Fig. 16.)

Collector—The collectors on the three-wire generator also require occasional attention and should be occasionally lubricated with slightly oiled canvas. If only slightly roughened, the rings can be trued up with the sandstone and sandpaper, otherwise they must be turned or ground.

Bearings—Westinghouse machines have self-oilingb earings. The oil-well should be filled to such a height that the rings will carry sufficient oil upon the shaft. If the bearings are too full, oil will be thrown out along the shaft. The oil should be renewed in small machines about once in six months, or oftener if it becomes dirty and causes the bearings to heat. Bearing housings are usually supplied with outlet holes for overflow of the oil. The oil should be kept slightly below the level of the holes.

The bearings must be kept clean and free from grit. They should be frequently examined to see that the oil supply is properly maintained and that the oil rings do not stick. Use only the best quality of oil. New oil should be run through a strainer if it appears to contain any foreign substance. If the oil is used a second time, it should first be filtered and, if warm, allowed to cool.

Turbine Bearings—For turbine units, a closed oiling system through which a continuous circulation is maintained by means of a pump geared to the main shaft of the turbine, keeps the turbine and generator bearings flooded with oil at a very moderate pressure. From the bearings, the oil drains through a strainer into a collecting reservoir, whence it is pumped through a cooler, and back to the bearings.

A warm bearing or a "hot box" is probably due to one of the following causes:

(1) No oil.

(2) Excessive belt tension.

(3) Failure of the oil rings to revolve with the shaft.

(4) Rough bearing surface.

(5) Improper fitting of the journal boxes.

(6) Bent shaft.

(7) Use of poor grade or dirty oil.

(8) Bolts in the bearing cap may be too tight.

(9) End thrust, due to improper leveling. A bearing may become warm because of excessive pressure exerted by the shoulder of the shaft against the side of the bearing.

(10) End thrust, due to the magnetic pull, rotating part being "sucked" into the field because it extends beyond the field poles further at one end than at the other.

(11) Excessive side pull, because the rotating part is out of center.

If a bearing becomes hot, first feed heavy lubricant copiously, loosening the nuts on the bearing cap; and then, if the machine is belt-connected, slacken the belt. If relief is not afforded, shut down, keeping the machine running slowly until the shaft is cool, in order that the bearing may not "freeze." Renew the oil supply before starting again. A new machine should always be run at a slow speed for an hour or so in order to see that it operates properly. The bearings should be carefully watched to see that the oil rings are revolving and carry a plentiful supply of oil to the shaft.

Belts—The belt on a belt-connected machine should be tight enough to run slowly without slipping, but the tension should not be too great or the bearings will heat. Belts should run with the inside lapping, not against it, and the joints should be dressed smooth so that there will be no jarring as it passes over the pulley. The crowns of driving and driven pulleys should be alike, as "wobbling" of belts is sometimes caused by pulleys having unlike crowns. If this is caused by bad joints, they should be broken and cemented over again. A wave motion or flapping is usually caused by slippage between the belt and pulley, resulting from grease spots, etc. It may, however, be a warning of an excessive overload. The fault may sometimes be corrected by increasing the tension, but a better remedy is to clean the belt. A back and forth movement on the pulley is caused by unequal stretching of the edges of the belt. If this does not cure itself shortly, examine the joints. If they are evenly made and remain so, the belt is bad and should be discarded.

Static Sparks from Belts—If sometimes occurs on belted machines, especially in dry weather, that charges of static electricity accumulate on the belt which may be of sufficiently high potential to cause discharges to ground. If the frame is not grounded, these charges may jump to the armature or field winding and thence to ground, puncturing the insulation.

The belt and frame may be discharged by placing a number of sharp metal points, which are carefully grounded, close to a belt at a point near the machine pulley. If the field frame is grounded, there should be no danger to the insulation.

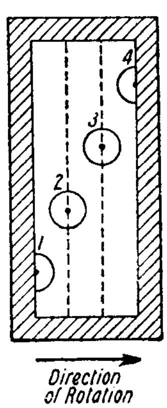


Fig. 17

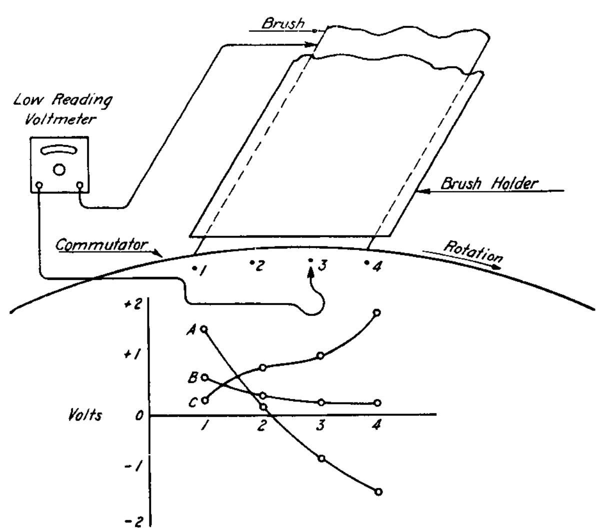


Fig. 18—Arrangement for Determining Proper Adjustment of Commutating-Pole Field

Sparking at the brushes may be due to any of the following causes:

(a) Commutating-pole field air gap may not be correct. The commutating-pole adjustment to give the best commutating conditions is made at the works and, in general, no reason for changing it after the machine is installed will arise. However, if such reason should arise, the proper change in excitation may be determined as follows:

With a low reading voltmeter read the voltage between the brushholder bracket and the commutator at four equi distant points across the face of the brush (along the circumference of the commutator) when the machine is running at normal load and voltage. These voltages can be most conveniently read by inserting a hard-wood or fibre block in an end brushholder having four radial holes correctly spaced in which the voltmeter "point" can be inserted. This is shown in Fig. 17. Readings should be taken from positions 1 to 4 in the direction of rotation. Take curves under both positive and negative brushes for several brush arms.

These readings, if plotted as shown in Fig. 18, indicate for example in curve "A" over compensation; i.e., excessive commutating field strength; curve "B" correct compensation; curve "C" under-compensation.

(b) The machine may be overloaded.

(c) The brush may not be set exactly on neutral.

(d) The brushes may be wedged in the holders or have reached the end of their travel.

(e) The brushes may not be fitted to the circumference of the commutator.

(f) The brushes may not bear on the commutator with sufficient pressure.

(g) The brushes may be burned on the ends.

(h) The commutator may be rough; if so it should be smoothed off.

(i) The commutator bar may be loose, or may project above the others.

(j) The commutator may be dirty, oily or worn out.

(k) The carbon brushes may be of an unsuitable grade.

(l) The brushes may not be equally spaced around the periphery of the commutator.

(m) Some brushes may have extra pressure and may be taking more than their share of the current.

(n) High mica.

(o) Vibration of the brushes.

(p) Incorrect brush angle.

These are the more common causes, but sparking may be due to an open circuit or loose connection in the armature. This trouble is indicated by a bright spark which appears to pass completely around the commutator and may be recognized by the scarring of the commutator at the point of open circuit. If a lead from the armature winding to the commutator becomes loose or broken, it will draw a bright spark as the break passes the brush position. This trouble can be readily located, as the insulation on each side of the disconnected bar will be more or less pitted.

The commutator should run smoothly and true, with a dark, glossy surface.

Heating of Field Coils—Heating of field coils may develop from any of the following causes:

(a) Too low speed.

(b) Too high voltage.

(c) Too great forward or backward lead of brushes.

(d) Partial short-circuit of one coil.

(e) Overload.

Heating of Armature—Heating of the armature may develop from any of the following causes:

(a) Too great a load.

(b) A partial short-circuit of two coils heating the two particular coils affected.

(c) Short-circuits or grounds on armature or commutator.

Heating of Commutator may develop from any of the following causes:

(a) Overload.

(b) Sparking at the brushes.

(c) Too high brush pressure.

(d) Lack of lubrication on commutator.

(e) Improper grade of brushes.

Bucking is the very expressive term descriptive of what happens when arcing occurs between adjacent brushholder studs. In general, bucking is caused by excessive voltage, or by abnormally low surface resistance on the commutator between brushholders of opposite polarity. Any condition tending to produce poor commutation increases the danger of bucking. Among other causes are the following:

(1) Rough or dirty commutator.

(2) A drop of water on the commutator, from the roof, leaky steam pipes or other source.

(3) Short-circuits on the line producing excessive overloads.

Cleanliness—Particular care should be exercised towards keeping all parts of the machines reasonably clean. This applies particularly to turbo-generators and other high-speed machines. The high rotative speed in these draws air into the armatures and other parts with a velocity sufficient to carry with it particles of dirt or oil vapor that may be in the air. The rotating part must be cleaned out as necessary or the machines will ultimately short-circuit between commutator necks or break down to ground over insulation surfaces. Some types of stationary windings should be well cleaned for the same reason, and more than merely blowing out with compressed air as described on Page 11 may be required.

In machines partially enclosed by solid end-bells, the end-bells should be removed regularly as required so that access may be had to all parts.

Maintenance

Ordering of Renewal Parts—Renewal parts of any standard Westinghouse generator or motor may be secured on short notice. To avoid misunderstanding always give the serial number of the stationary or of the rotating part of the machine, as the case may be. The former will be found stamped on the name plate and the latter on the end of the shaft. When material for coils is ordered it should be stated whether or not insulation for the winding is also desired.

Save the shipping notices sent when the apparatus is shipped as they give the number of our shop orders on which the apparatus has been built and this "S.O." number is an excellent means of identification. It materially assists in quickly locating all records regarding the parts.

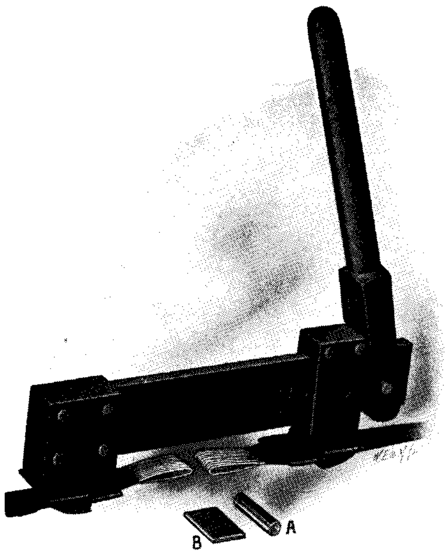


FIG. 19

Rebabbitting Bearings—The old babbitt should first be melted out and a suitable mandrel prepared. Split bearings should be babbitted one half at a time, and the mandrel should consist of a half-cylinder with shoulders running along its length on which the sides of the bearings may rest, so as to form a close fit when the bearing housing is in position for babbitting. Pieces of felt should be placed between the ends to prevent the babbitt from running into the oil well in the spaces back of the bearing shell. Use only the best babbitt metal. The melted babbitt should be poured into the gate until it begins to overflow, and a few moments should elapse before it is removed from the mandrel, in order that the bearing may become quite hard. The bearing housing should then be bored or reamed to the proper size, the holes for inspecting the working of the oil rings drilled, and the oil ring slots melted or cut to the proper depth. The finishing can be done with a file. If the mandrel is a smooth half-cylinder the oil grooves should be chipped out. The grooves may be cast by properly designing the mandrel.

Repairs to Insulation—If a defect develops in the outside of a field or armature coil, it can sometimes be repaired by carefully raising the injured wire or wires and applying fresh insulation. More extensive repairs should not be attempted by inexperienced or unskilled workmen.

If it is desired to remove one of the commutating-pole coils loosen the bolts which hold the pole to the frame and disconnect the coil from those on each side. The pole-piece and coil can then easily be removed from the frame.

In case of desiring to remove a shunt or series field coil the bolts holding the pole-pieces should be removed. This will make it possible to remove the pole-piece and coil, after which a new pole piece with its coil can be installed. Care should be taken in reconnecting the coil, placing so as to obtain the proper polarity of the coil. A very simple means of testing the polarity is by means of a needle or a piece of steel wire suspended from the middle by a string. The polarity should be alternately north and south around the frame. Bring the polarity needle within the magnetic field of any pole. One end of the needle will point towards this pole and this end should be repelled by the next pole and so on around the frame. If this reversal of the needle does not occur there must be a wrong connection of the field coil.

Armatures—A simple method of making temporary repairs in an armature in case of a short-circuit or open circuit of one of the coils is to cut out that coil by cutting the leads which connect the coil with the commutator bar and then short-circuiting the bar, thus cut out, with the following bar. This may readily be done by simply soldering the two necks together. By this means an armature may be kept in commission until there comes a convenient time to replace the damaged coils.

Sectional Bands—In repairing direct-current armature windings, particularly large ones, the replacing of band wires becomes a serious problem. To overcome this difficulty, the Westinghouse Company has designed a form of sectional band which retains all the elements of a continuous wire band, yet can be applied or removed quickly and repeatedly without deterioration. These bands are regularly supplied on armatures having a diameter of 50 inches or greater.

Figs. 19 and 20 show the tool employed to mount these bands in position. One of these tools is furnished with each machine equipped with sectional bands.

To make the final connection between the free ends, after the different sections have been keyed together into an open hoop and are in position on the armature, place the tool as shown in Fig. 19, the two jaws gripping the projecting ends of the fixed pieces let into the ends of each section for the purpose. With the tool in the position shown in Fig. 19, bring down the handle to position of Fig. 20, forcing the movable jaws forward along the beam and interweaving the loops on the section ends. Insert the steel pin A in the holes through the movable jaw and beam, and with the tool clamped in this way remove the handle and advance it to the next hole in the beam. This operation is repeated until the ends of the band are interlocked sufficiently to permit the steel key piece B to be inserted (See Fig. 20). All that remains is to remove the tool and paint or shellac the joint.

To remove the band, reverse the preceding process. Relieve the tension on the joint by tightening the band with the tool and then drive out the key piece.

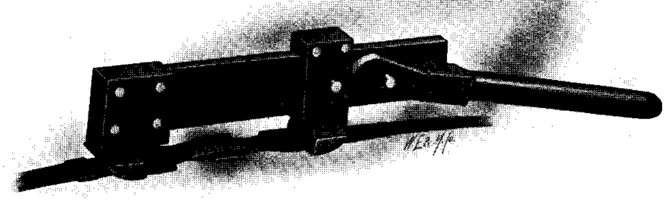


FIG. 20

Diagrams of Connections

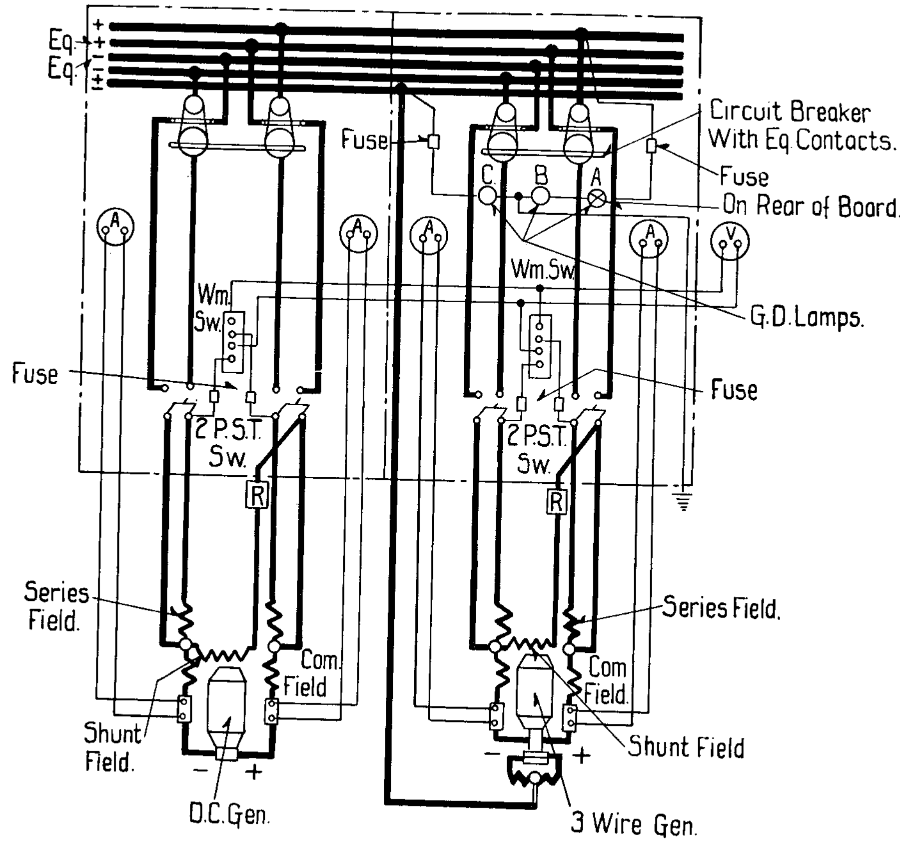


Fig. 21—Diagram of Connections for One Three-Wire Commutating-Pole, 125—250-Volt D-C. Generator in Parallel With One Two-Wire 240-Volt Generator

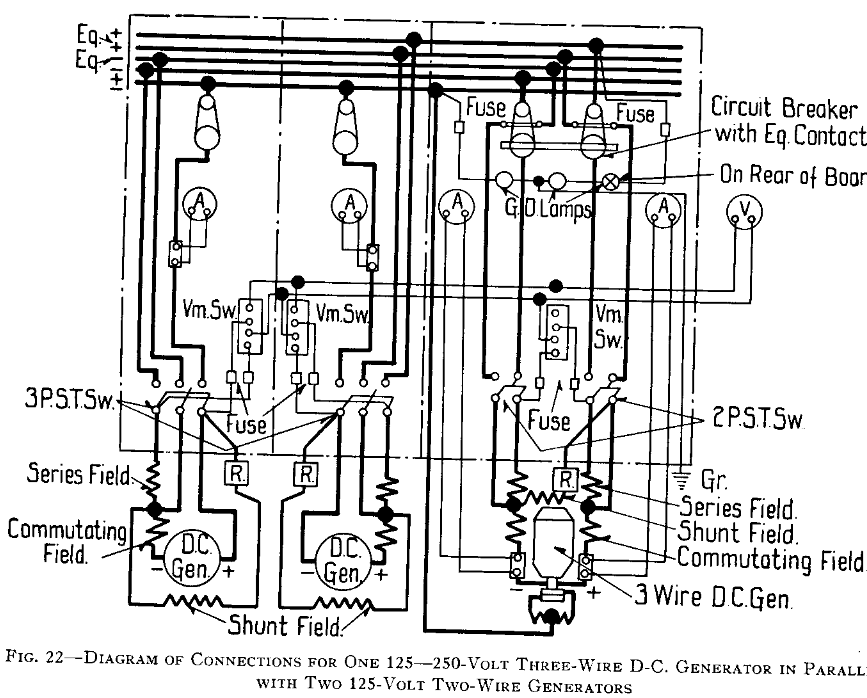


Fig. 22—Diagram of Connections for One 125—250-Volt Three-Wire D-C. Generator in Parallel with Two 125-Volt Two-Wire Generators

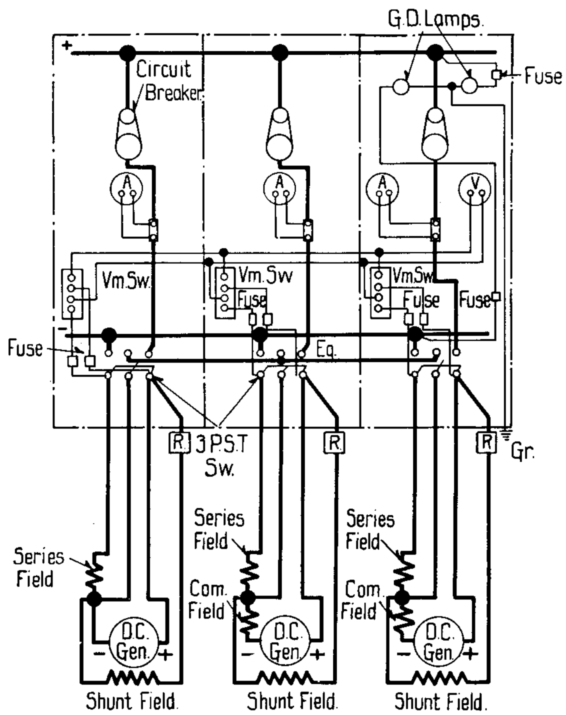


FIG. 23—DIAGRAM OF CONNECTIONS FOR TWO D-C. COMMUTATING-POLE GENERATORS IN PARALLEL WITH ONE D-C. NON-COMMUTATING-POLE GENERATOR. TYPE GD SWITCHBOARD, 250 VOLTS OR LESS

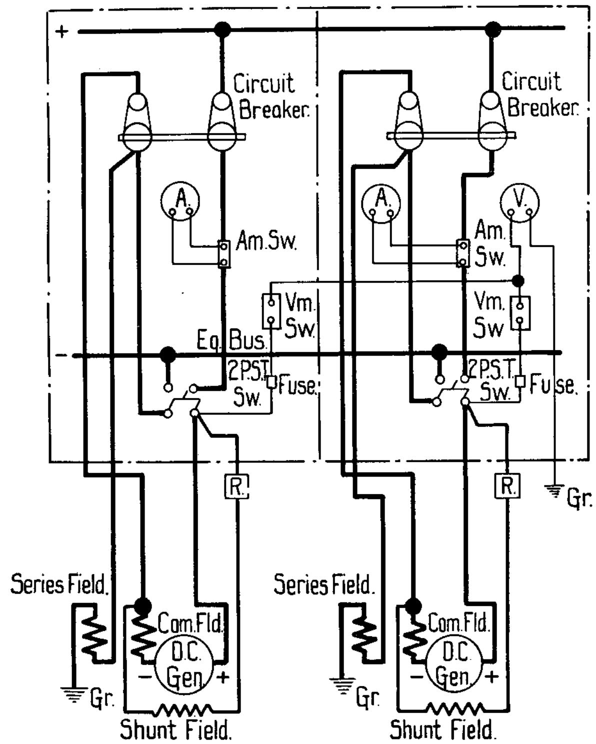


FIG. 24—DIAGRAM OF CONNECTIONS FOR TWO COMMUTATING-POLE ENGINE-DRIVEN MINE GENERATORS IN PARALLEL

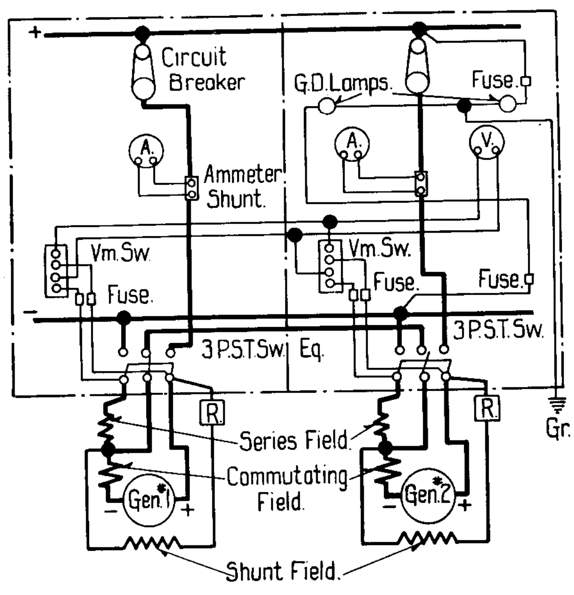


FIG. 25—DIAGRAM OF CONNECTIONS FOR TWO D-C. COMMUTATING-POLE GENERATORS. TYPE GD, SWITCHBOARD, SINGLE BUS SYSTEM, 250 VOLTS OR LESS

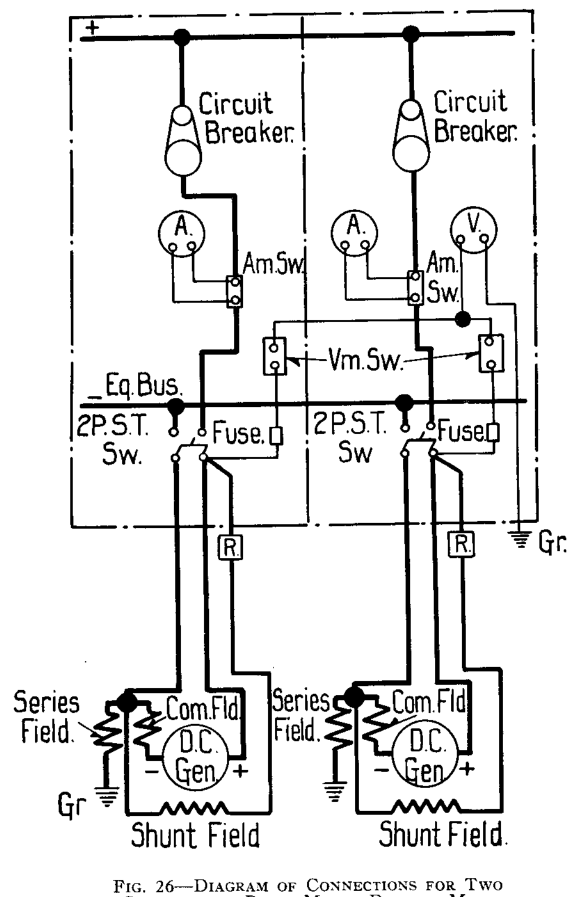
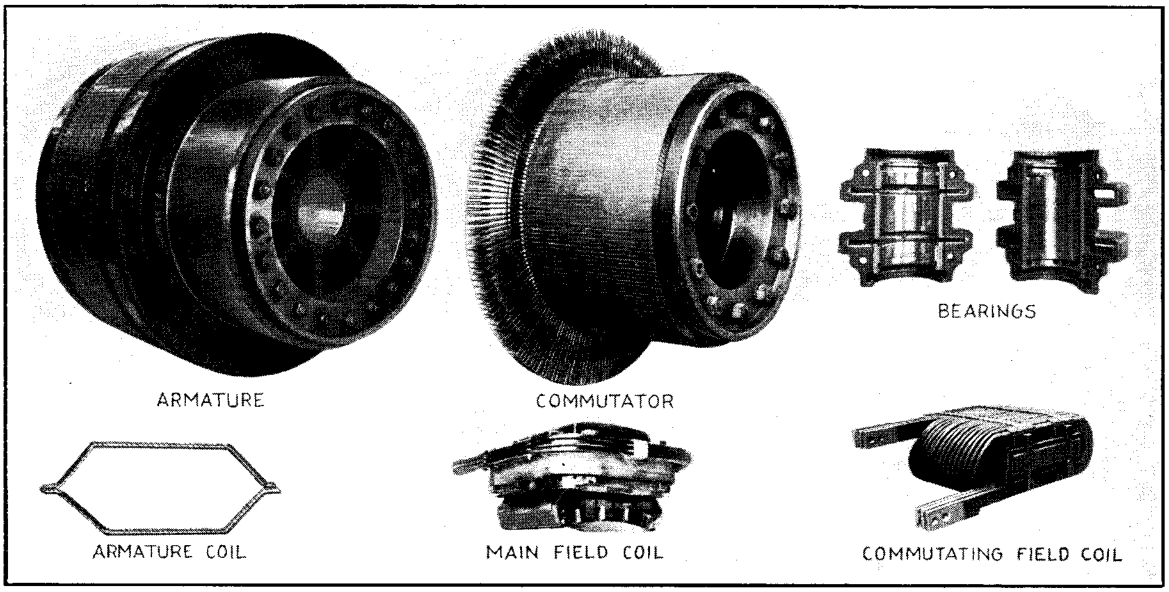
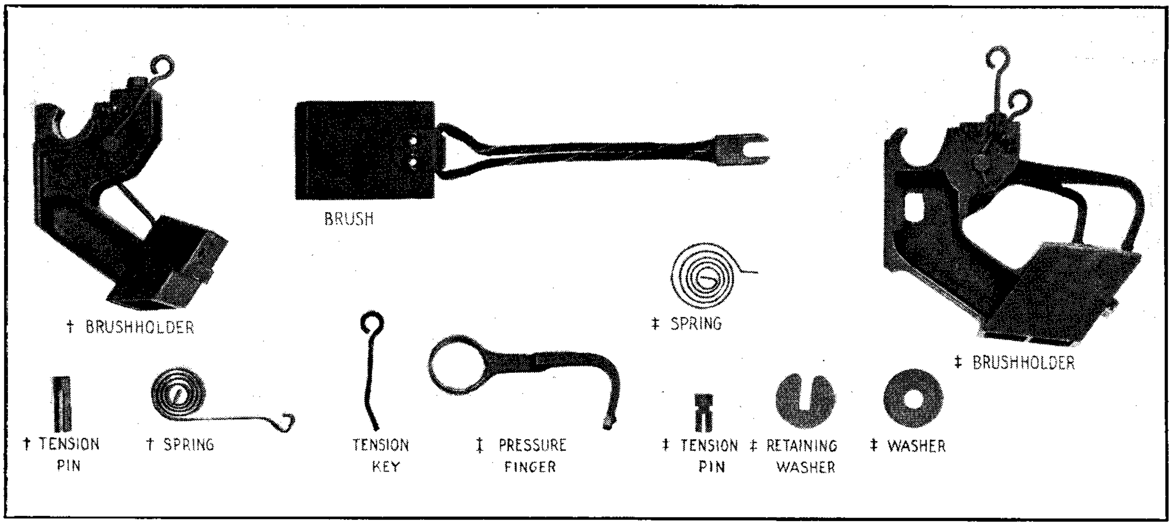


FIG. 26—DIAGRAM OF CONNECTIONS FOR TWO COMMUTATING-POLE MOTOR-DRIVEN MINE GENERATORS IN PARALLEL

Recommended Stock of Renewal Parts





†Single Brushholder ‡Double Brushholder

FIG. 27—TYPICAL RENEWAL PARTS FOR DIRECT-CURRENT GENERATORS AND MOTORS

Total number of units up to and including		1	5
Name of Part	**No. Per Unit**	**Recommended For Stock**	
Armature Complete	1	0	0
Armature Coil	1 set	1/3 set	1 set
*Cut Winding Insulation, Class No. 1	1 set	1/3 set	1 set
Commutator	1	0	0
Field Coil, Main	1 set	1	3
Field Coil, Commutating	1 set	1	3
†‡Brushes	1 set	1 set	3 sets
†‡Brushholder	1 set	0	½ set
†‡ Tension Pin	1 set	1	2
†‡ Tension Key	1 set	1	2
†‡ Spring	1 set	1	2
‡ Pressure Finger (short or long)	1 set	0	1
‡ Retaining Washer	1 set	2	4
‡ Washer	1 set	2	4
Bearings	2	1	2

Parts indented are included in the part under which they are indented.
*Not illustrated.
†Single Carbon Brushholder (Specify which is desired).
‡Double Carbon Brushholder (Specify which is desired).

This is a list of the Renewal Parts and the quantities of each that we recommend should be stocked by the user of this apparatus to minimize interrupted operation caused by breakdowns. The parts recommended are those most subject to wear in normal operation or those subject to damage or breakage due to possible abnormal conditions.

This list of Renewal Parts is given only as a guide. When continuous operation is a primary consideration, additional insurance against shutdowns is desirable. Under such conditions more renewal parts should be carried, the amount depending upon the severity of the service and the time required to secure renewals.

ORDERING INSTRUCTIONS

Name the part. Give the complete name plate reading. State whether shipment is desired by express, freight or by parcel post. Send all orders or correspondence to nearest sales office of the Company. Small orders should be combined so as to amount to a value of at least one dollar, as order-handling and shipping expenses prevent us from billing a smaller amount.